

# SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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# SCOPE, SEQUENCE, and COORDINATION

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\*\* Not part of the NSF-funded SS&C project.

## National Science Education Standard—Life Science

### The Molecular Basis of Heredity

Most of the cells in a human contain two copies of each of 22 chromosomes. In addition, there is a pair of chromosomes that determines sex: a female contains two X chromosomes and a male contains one X and one Y chromosome. Transmission of genetic information to offspring occurs through egg and sperm cells that contain only one representative from each chromosome pair. An egg and a sperm unite to form a new individual. The fact that the human body is formed from cells that contain two copies of each chromosome—and therefore two copies of each gene—explains many features of human heredity, such as how variations that are hidden in one generation can be expressed in the next.

In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kinds (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular “letters”) and replicated (by a templating mechanism). Each DNA molecule in a cell forms a single chromosome.

Changes in DNA (mutations) occur spontaneously at low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Only mutations in germ cells can create the variation that changes an organism’s offspring. [Editor—Recombinations and crossing over are also factors.]

## Teacher Materials

Learning Sequence Item:

# 902

## Variation and Heredity

August 1996

Adapted by: Godrej Sethna

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**Traits, Genes, Chromosomes, and DNA.** Students should observe continuous and discontinuous variation and consider their causes. They can examine examples of discreteness and blending using certain plant and animal pedigrees. Students should observe Mendelian principles of dominance, segregation, and independent assortment and experience these principles using Mendel’s historical approach of “discrete factors.” Punnet squares can be introduced to examine these crosses (*Biology, A Framework for High School Science Education, p. 103*).

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# 902

## Learning Sequence

**Traits, Genes, Chromosomes, and DNA.** Students should observe continuous and discontinuous variation and consider their causes. They can examine examples of discreteness and blending using certain plant and animal pedigrees. Students should observe Mendelian principles of dominance, segregation, and independent assortment and experience these principles using Mendel's historical approach of "discrete factors." Punnet squares can be introduced to examine these crosses (*Biology, A Framework for High School Science Education, p. 103*).

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
<p>Individual Differences <b>Activity 1</b></p> <p>Yellow or . . . <b>Activity 2</b></p> <p>Tales of Data <b>Activity 4</b></p> <p>Plant Genetics <b>Assessment 1</b></p>	<p>Fast Plants <b>Assessment 2</b></p> <p>Student Statistics <b>Assessment 7</b></p>	<p>Steven Thacker <b>Activity 3</b></p> <p>Human Pedigrees <b>Assessment 3</b></p> <p>What's Right About Being Left-Handed? <b>Reading 1</b></p>	<p>Animal Genetics <b>Assessment 4</b></p> <p>January Rainfall <b>Assessment 5</b></p> <p>People Sizes <b>Assessment 6</b></p>

## Suggested Sequence of Events

### Event #1

#### Lab Activity

1. Individual Differences (30–45 minutes)

### Event #2

#### Lab Activity

2. Yellow or . . . (30 minutes)

### Event #3

#### Lab Activity

3. Steven Thacker (45 minutes)

### Event #4

#### Lab Activity

4. Tales of Data (30–40 minutes)

### Event #5

#### **Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science.**

**The following reading is included in the student version of the unit:**

Reading 1 What’s Right About Being Left-Handed?

#### **Suggested additional readings:**

“A Mystery in Your Lunchbox.” *Newsweek*, June 8, 1992, pp. 48–49.

Gates, D., J. McCormick, and G. Carroll, “An American Tragedy in Iowa.”

*Newsweek*, February 7, 1994, pp. 44–.

“Solving Knotty Problems in Math and Biology.” *Science*, Vol. 231, Article #51,

March 28, 1986, pp. 1506–1508.

Offner, S., “A Plain English Map of the Human Chromosomes.” *The American*

*Biology Teacher*, February 1992, pp. 87–91.

*Assessment items can be found at the back of this volume.*

## **Assessment Recommendations**

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.
2. Open-ended questions asking for essay responses.
3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

## Science as Inquiry

**Individual Differences****Can a small sample show variety?****Overview:**

This activity is designed to make students aware that some characteristics (traits) are expressed along a continuum. It establishes the occurrence of continuous variation using students' eye color and height as examples. The data from this activity will be used again in Activity 4, "Tales of Data."

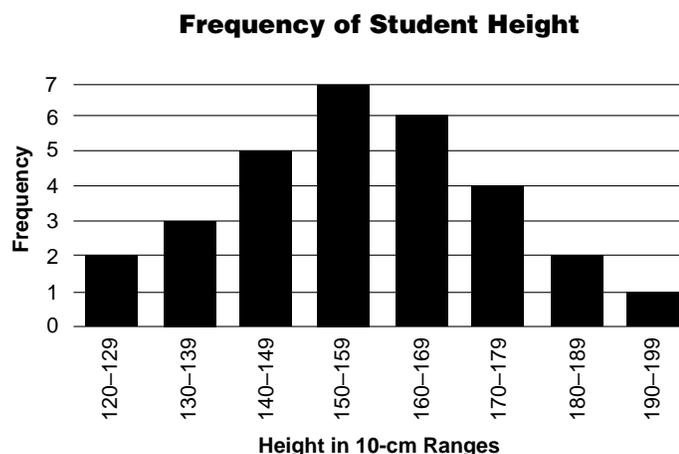
**Materials:****Per lab group:**

- meter stick
- metric ruler
- graph paper, 2 sheets per student
- seeds (optional)
- plastic containers, clear and of equal size (to hold seeds) (optional)

**Procedure:**

Students observe and record two human traits that are continuous (nondiscrete), eye color and height. After lab groups have recorded eye colors of group members, help them organize the data collected from the whole class to see that there is a whole range of eye colors. A histogram of commonly recognizable eye colors may be used in discussion. Color of the human iris ranges from nearly black to blue, with brown, hazel, green, and gray in between. Since each class should represent a random sampling of the student population as a whole, data from other classes should appear similar. Some eye colors are harder to identify, and the problem may be compounded by the presence of color-blind males in your class.

It is important that students measure height under identical conditions. Remind them about possible sources of error, such as footwear, parallax, position of meter stick, and posture. You may have to help them organize the data collected by the whole class. They should then plot a graph of the data. To facilitate graphing, student heights may be grouped in 10-cm ranges, for example, 100–109, 110–119, 120–129, 130–139, and so on.



**Background:**

This activity is designed to make students aware that some characteristics (traits) are expressed along a continuum. Such traits are often referred to as quantitative and are generally due to control by two or more different genes (polygenic), together with lack of dominance between alleles (pairs of genes that determine a single trait). In the case of human height, the effect of the various genes add up (additive gene action) to manifest the characteristic. The graph of students' heights will show a general pattern like the one included above.

**Variations:**

Several other characteristics may be used in place of height, such as length of index finger, shoe size, arm length, hand span, and cubit. Length of seeds could also be used. If you decide to use seeds for the activity, you may want to make a 3-D graph. Students should sort seeds by length and place them in clear containers of equal size. Containers are then arranged in ascending order by length of seeds. You will need to use seeds from the entire class for this visual aid.

Adapted from:

Campbell, N. A., *Biology*, 2nd Edition. Redwood City, Calif.: Benjamin/Cummings Publishing, 1990.  
Crow, L. W. and G. H. Sethna, *Patterns*. Houston: Texas Scope, Sequence, and Coordination Project, 1993.

Morholt, E. and P. F. Brandwein, *A Sourcebook for the Biological Sciences*. Fort Worth, Tex.: Harcourt Brace Jovanovich College Publishers, 1986.

Nelson, G. E. and G. G. Robinson, *Fundamental Concepts of Biology*, 4th Edition. New York: John Wiley, 1982.

## Science as Inquiry

**Yellow or . . .****How do organisms exhibit discontinuous variation?****Overview:**

This activity demonstrates discontinuous (discrete) variation using traits of two different plant species. The seeds will have to be planted at least 10–12 days before the activity is scheduled.

**Materials:****Per class:**

soybean seedlings (grown in flats), 125–150  
 corn seedlings (grown in flats), 100–125  
 graph paper, 2 sheets per student

**Procedure:**

Students identify three different types of soybean seedlings, yellow, yellow-green, and green, and count the number of each type. They then draw a bar graph of their observations and calculate the ratio of the three types. The graph will look like the one shown in Figure 1.

Next, students count the number of corn seedlings of the two types (green and albino), draw a graph, and calculate the ratio of the two types. The graph for corn seedlings will look like the one shown in Figure 2.

**Background:**

The two examples used in this activity show discontinuous (or discrete) variation. The colors found in leaves of soybean seedlings are a result of incomplete dominance in which the genes for

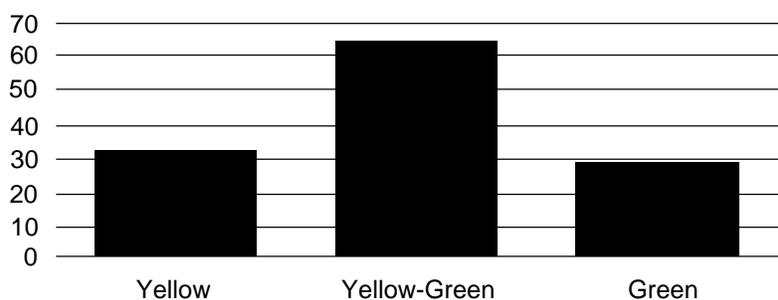
**Number of Soybean Plants Sorted by Type**

Fig. 1

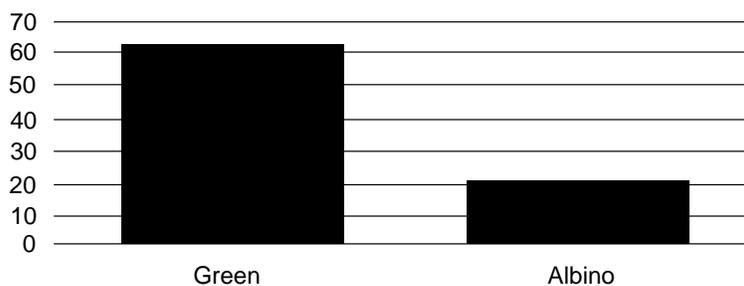
**Number of Corn Plants Sorted by Type**

Fig. 2

green and yellow are equally dominant. Therefore, the seedlings that are heterozygous (containing genes for yellow and green) will show a color that is a “blend” of the two (yellow-green). This is often referred to as *intermediate inheritance*. The ratio of yellow:yellow-green:green is 1:2:1. The corn seedlings will be green or albino, and the ratio of green:albino will be 3:1. The numbers collected by students will not be exact but will show these ratios.

Unlike soybeans, the phenotype for albino corn seedlings is recessive and the phenotype for green corn seedlings is dominant. Such a trait is called discrete, because the corn seedlings can be classified into two distinct groups—green or albino. This sequence of experiences for students is deliberately planned so that they encounter the phenomenon of incomplete dominance first. In arriving at an explanation for this kind of inheritance, students are more likely to discover the need for two factors (a pair of alleles) for each trait.

The seeds will have to be planted at least 10–12 days before the activity is scheduled. The germination rate depends, in part, on the temperature. You may want to grow just one batch of seeds of each kind and let all your classes use them. The albino corn will not survive for very long as it lacks the pigment necessary for photosynthesis. The seeds may be obtained from sources like the Carolina Biological Supply Company. If you wish to order from Carolina Biological, the following information may be useful:

Soybean seeds, green:yellow-green:yellow (1:2:1), Catalog Number F6-17-8200

Corn seeds, green-albino (3:1), Catalog Number F6-17-7130

One packet of soybean seeds holds about 150 seeds. One packet of corn seeds has approximately 100 seeds.

### **Variations:**

Other organisms may be substituted for corn or soybean plants. Human characteristics that are discrete, such as handedness, tasting of PTC, and attached or free earlobes, may also be used for this activity. Contrary to popular belief, ambidexterity is a learned characteristic.

Adapted from:

Crow, L. W. and G. H. Sethna, *Patterns*. Houston: Texas Scope, Sequence, and Coordination Project 1993.

Morholt, E. and P. F. Brandwein, *A Sourcebook for the Biological Sciences*. Fort Worth, Tex.: Harcourt Brace Jovanovich College Publishers, 1986.

Science in Personal and  
Social Perspectives

## Steven Thacker

### How does our genetic ancestry affect us?

#### Overview:

This activity uses a human example to add to students' understanding of the inheritance of discrete traits. Students read a fictitious account and work with a typical pedigree chart.

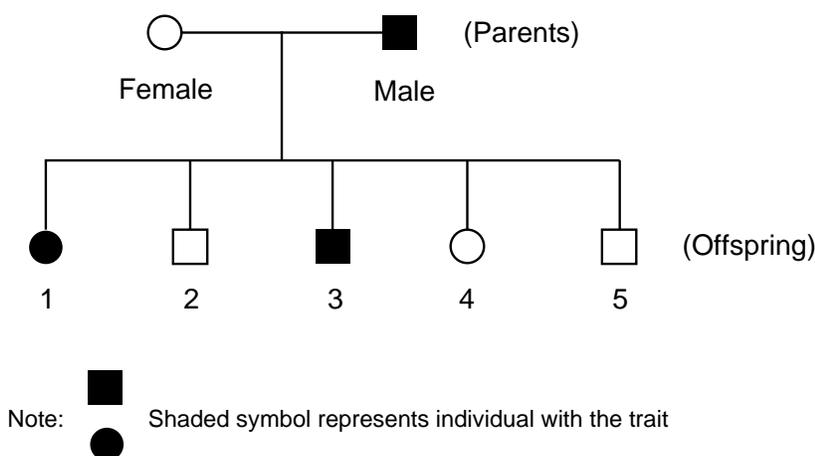
#### Materials:

##### Per lab group:

pedigree chart (included with Student Materials)  
pencil or pen

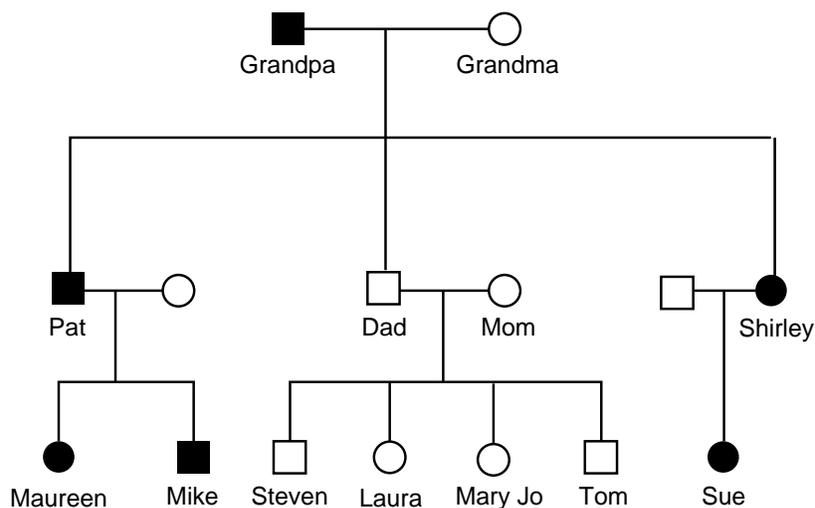
#### Procedure:

Students read the story about Steven Thacker and his relatives. A number of Steven's relatives have polydactyly. Polydactyl individuals have more than five fingers on a hand. After reading the story, students attempt to create a pedigree chart and then participate in a class discussion.



#### Background:

Some of the techniques used to examine human inheritance are different than those used in studying plants and animals. This is due, in part, to relatively low birth rate (as compared to fruit flies and other organisms of choice used in genetics) and the long life of generations. Analysis of pedigree charts is a tool used in human genetics. A pedigree chart is a graphic representation of relationships among individuals spanning several generations and is usually drawn to show the pattern of inheritance of one specific trait. In a pedigree chart, female individuals are represented by circles and males by squares. A horizontal line between two individuals shows parental relationship. When a symbol for an individual (either female or male) is shaded or filled it shows that the person has the characteristic (trait) under investigation. Clearly, in this case the trait is question appears each generation and is not related to



The Completed Pedigree Chart of Steven Thacker's Family

gender; that is, it is not sex-linked. This would be consistent with an inheritance pattern for an autosomal dominant trait from a heterozygous male (Grandpa). Note: examination of characteristics, identification of a trait, and determination of how a trait varies and its apparent pattern of inheritance is of prime importance. No mention of DNA, genes, or chromosomes is necessary at this time. These topics will be studied at higher grade levels.

Adapted from:

*Biological Science: Patterns and Processes*, 3rd Edition (E. A. Combs, Ed.). Dubuque, Iowa: Kendall/Hunt, 1986.

Morholt, E. and P. F. Brandwein, *A Sourcebook for the Biological Sciences*. Fort Worth, Tex.: Harcourt Brace Jovanovich College Publishers, 1986.

Nelson, G. E. and G. G. Robinson, *Fundamental Concepts of Biology*, 4th Edition. New York: John Wiley, 1982.

## Science as Inquiry

**Tales of Data****What is the meaning of “mean”?****Overview:**

Students use data collected from Activity 1, “Individual Differences,” to calculate the mean. They then consider the significance of the arithmetic mean in terms of variation and its causes.

**Materials:****Per class:**

data from Activity 1, “Individual Differences”

**Procedure:**

Students use the data collected from Activity 1, “Individual Differences,” to calculate the mean. In Activity 1, height of each class member was measured, the data were grouped in 10-cm ranges (for example, 130–139 cm), and a graph was plotted. One question to be asked is: how does one calculate the mean of such “grouped” data?

Let us assume that the data looked like those shown in Column A of the table below. The next step is to find the midpoint of each group of data. In our example, 124.5 is the midpoint between 120 and 129, 134.5 is the midpoint between 130 and 139, and so on. Midpoints are shown in Column B. Column C shows the number of students (frequency) whose height was in that group, which means that two students had heights in the 120–129 cm range, three students had heights in the 130–139 cm range, and so on.

The next step is to multiply midpoint (MP) by frequency (F) for each row. For example,  $124.5 \times 2 = 249.0$ ;  $134.5 \times 3 = 403.5$ ; and so on. These figures are shown in Column D. Add all the numbers shown in Column C, which in our example add to 30. This is the sum of F. Similarly, add all the numbers in Column D ( $F \times MP$ ), which sum to 4,705. To calculate the mean height of students in the class divide 4,705 by 30. The result is 156.83 cm.

COLUMN A	COLUMN B	COLUMN C	COLUMN D
Height in cm	Midpoint (MP)	Frequency (F)	F × MP
120–129	124.5	2	249.0
130–139	134.5	3	403.5
140–149	144.5	5	722.5
150–159	154.5	7	1,081.5
160–169	164.5	6	987.0
170–179	174.5	4	698.0
180–189	184.5	2	369.0
190–199	194.5	1	194.5
<b>Sums</b>		<b>30</b>	<b>4,705.0</b>

$$\text{Mean} = \text{Sum of } (F \times \text{MP}) / \text{Sum of } F = 4,705/30 = 156.83 \text{ cm}$$

**Background:**

The mean is used to represent a group of data when it is inconvenient and time consuming to enumerate all the data. The mean (also called arithmetic mean) is a measure of central tendency of a set of observations or other quantifiable data. In everyday language it is referred to as the average. Finding the average of a list of numbers is a simple two-part mathematical operation. However, when the data are expressed as a range of numbers (for example, 61–65, 66–70, and so on), it becomes necessary to use a different procedure to calculate the mean. The mathematical operations to do such a calculation for grouped data are described above.

It is interesting for students to compare the mean value of individual height measurements and the mean calculated in this activity. A discussion of such a comparison would be worthwhile in terms of the meaning of “mean.” Furthermore, by considering what would happen to the calculated mean if five new students were added to one height range, students will gain valuable experience in preparation for more advanced statistical analysis at higher grade levels.

**Variations:**

You may wish to supply students with several sets of data to give them practice. One alternative is to use data that were collected by different classes.

Adapted from:

Guilford, J. P., and B. Fruchter, *Fundamental Statistics in Psychology and Education*. New York: McGraw-Hill, 1973.

Morholt, E., and P. F. Brandwein, *A Sourcebook for the Biological Sciences*. Fort Worth, Tex.: Harcourt Brace Jovanovich College Publishers, 1986.

## Science as Inquiry

**Plant Genetics****Item:**

Your teacher will provide examples of flower species, labeled 1st, 2nd, and 3rd generation, that may include photos, descriptions, pressed specimens or live plants. Observe the colors of the flowers of each species and look for patterns in the ways the flowers inherit characteristics. Describe the pattern or patterns you observe.

**Answer:**

The specimens should include purebred parents, their F offspring, and the F<sub>2</sub> generation (labeled 1st, 2nd, 3rd generation). Examples should include varieties with complete dominance and incomplete dominance.

## Science and Technology

**Fast Plants****Item:**

Scientists have genetically engineered a population of mustard plants that grows and produces seeds very quickly. Prepare a detailed proposal for carrying out a cross-pollination study with these “fast plants.” Include descriptions of how you will record and analyze information from the study.

If time permits, grow samples and cross-pollinate them with other varieties of “fast plants.” Predict the results in leaf characteristics, height, flower characteristics, etc. When the second generation is mature, observe and record the results.

**Answer:**

This assessment obviously would be conducted over a period of time. Assessment of student understanding of how to conduct a simple research study will be achieved by having them just prepare a proposal.

## Science in Personal and Social Perspectives

**Human Pedigrees****Item:**

Construct a pedigree chart of your own family or the family of a friend, going back two generations if possible (to your parents and grandparents). Choose a number of traits, such as height, hair color and texture, eye color, earlobe shape, and finger interlacing. When you have finished, examine your results. Decide which traits show discrete inheritance patterns and which show blending. Explain your choices.

**Answer:**

This assessment is directly related to the activities in this unit. You will want to customize it to assess how well students can construct charts and you should use slightly different traits than those directly studied in class. The amount of time needed will depend on the complexity of the assigned task.

## History and Nature of Science

**Animal Genetics****Item:**

In many domestic animals, selective breeding has led to problems such as hip dislocations, fragile bones, heart defects, high risk of cancer, etc. Why would breeding for fur color, posture, speed, etc., have an effect on these other traits?

**Answer:**

Selection for one gene (allele) may mean that automatic selection for a gene that is not desired happens at the same time, thus perpetuating an undesirable trait. Breeders are reluctant to avoid using animals that have undesirable characteristics if the animals are particularly strong in the desired characteristic, although some breeders' associations may have asked breeders to take such action.

As a follow-up, you may wish to ask students to research information (library and interview) about known deleterious traits in a specific purebred animal and how attempts have been made to deal with this issue over many years. This will be particularly useful if the area around the school has many breeding locations (i.e., for horses, fish, dogs, etc.).

## History and Nature of Science

**January Rainfall****Item:**

Rainfall measurement records for Seaview (a town on the California coast of the Pacific Ocean) are:

Average for January all years	Total for January this year	Total for January last year	Total for January two years ago
6.0	6.6	4.3	2.

Values are given in inches.

Rainfall total for January this year could be described as:

- A. normal
- B. greatly more than expected
- C. greatly less than expected
- D. abnormally high.

**Justification:**

When are data considered “normal”?

**Answer:**

A. The student should provide evidence of understanding that “normal” data may fall within a range of values roughly centered around an average of all recorded values. Furthermore, the student should express understanding of how the average value is calculated.

Science in Personal and  
Social Perspectives

**People Size**

**Item:**

Over the centuries, the average size of people has changed. What factors may have caused this change?

**Answer:**

An increase in the availability of nutritious foods may account for this change. In addition, increased body size may be favored by natural selection. You should be wary of Lamarckian interpretations in explanations by students. For example, the development of the giraffe's neck as explained by Lamarck would involve giraffes in each generation stretching and developing their necks and passing the development on to their offspring. Environmentally induced traits cannot be passed on to subsequent generations.

## Science and Technology

**Student Statistics****Item:**

Propose a characteristic of students that can be easily measured but that you did not measure in this unit. State what you think the mean value and distribution will be for students in:

- A. your class
- B. your school

Explain why you think there may be differences between the results for A and B. Suggest a plan for collecting data to determine A and B. For B, you may find a way to collect data without measuring or interviewing every student in the school. If your plan is approved by your teacher, collect the data and prepare a report that will demonstrate the values clearly to your classmates.

**Answer:**

In conjunction with Activity 1, “Individual Differences,” choices might include foot length, hand length, length of first finger, and arm spread, as well as items over which students have some control, such as hair length, waist size, grades. They should be encouraged to think about the difference between uncontrollable variables and variables under personal control (fads, etc.). They could also include items not subject to linear measurement but which change in discrete units. Special statistics apply to these Poisson distributions, but the results are not that different from Gaussian or normal distributions. Deciding how to collect and scale the results is intriguing (such as with hair or eye color, preference of music, movies, etc.) as is how to present results in ways beyond the simple histogram usually done by younger students.

<b>Consumables</b>		
<b>Item</b>	<b>Quantity per lab group</b>	<b>Activity</b>
corn seedlings (grown in flats)	100–125	2
graph paper	2 sheets per student	1, 2
pedigree chart (included with Student Materials)	1	3
seeds (optional)	—	1
soybean seedlings (grown in flats)	125–150	2

<b>Non-Consumables</b>		
<b>Item</b>	<b>Quantity (per lab group)</b>	<b>Activity</b>
meter stick	1	1
metric ruler	1	1
pencil or pen	1	1, 2, 3, 4
plastic containers (clear, of equal size) (optional)	—	1

**Key:**

1. Individual Differences
2. Yellow or . . .
3. Steven Thacker
4. Tales of Data

**Activity Sources**

- Biological Science: Patterns and Processes*, 3rd Edition (E.A. Combs, Ed.). Dubuque, Iowa: Kendall/Hunt, 1986.
- Campbell, N.A., *Biology*, 2nd Edition, Redwood City, Calif.: Benjamin/Cummings Publishing, 1990.
- Crow, L.W. and G.H. Sethna, *Patterns*. Houston: Texas Scope, Sequence, and Coordination Project, 1993.
- Guilford, J.P. and B. Fruchter, *Fundamental Statistics in Psychology and Education*. New York: McGraw-Hill, 1973.
- Morholt, E. and P. F. Brandwein, *A Sourcebook for the Biological Sciences*. Fort Worth, Tex.: Harcourt Brace Jovanovich College Publishers, 1986.
- Nelson, G.E. and G.G. Robinson, *Fundamental Concepts of Biology*, 4th Edition. New York: John Wiley, 1982.

**Student Readings**

- Ponte, L., "What's Right About Being Left-Handed?" *Reader's Digest*, July 1988, pp. 133–137.